REPORT STAT

EVALUATING THE REQUIREMENTS OF A CLEANROOM LIQUID BEARING MODULE

RM-139-65

June 1965

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FOREWORD

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[redacted] submits this report in compliance with Item 4.2 of the Development Objectives of [redacted]

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ABSTRACT

Some of the design parameters that would form the basis for the design of a modular film processor compatible with cleanroom environments are presented. There is indication that such an approach is feasible, presenting the possibility of designing flexible processors, adaptable to wide ranges of processing specifications.

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ILLUSTRATIONS

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1. INTRODUCTION

[redacted] has produced processors to handle all processing techniques over the full range of specifications common to the art. However, each processor has been designed and constructed for a particular process. Some of the more advanced processors have included means of controlling many of the specified parameters, providing considerable flexibility and precise control of the resultant output. Consideration should be given to a new approach to processor design. The objective should be a processor adapted even more flexibly, not only to control parameters in a given processing sequence, but to extend the use of a processor to all ranges of photographic emulsions. An approach to this philosophy of processing is a modular processor in which major variations can readily be introduced by changes in the number of solution tanks. This arrangement allows changes in solution temperatures and in the relative times the emulsions are in contact with the solution in each stage of the process.

2. TECHNICAL DISCUSSION

2.1 GENERAL

The concept of the modular processing machine can be considered both from the point of view of the entire machine and of the component modules. In essence, there will be a basic structure including a loading module, a drying module, a base, and a control console. Between the load module and the drying module will be two or more solution modules and the inter-module air bearing transfer units, as shown in Figure 1.

Certain basic conditions are established which must be met by the processor. These include:

1) Compatibility with cleanroom operation

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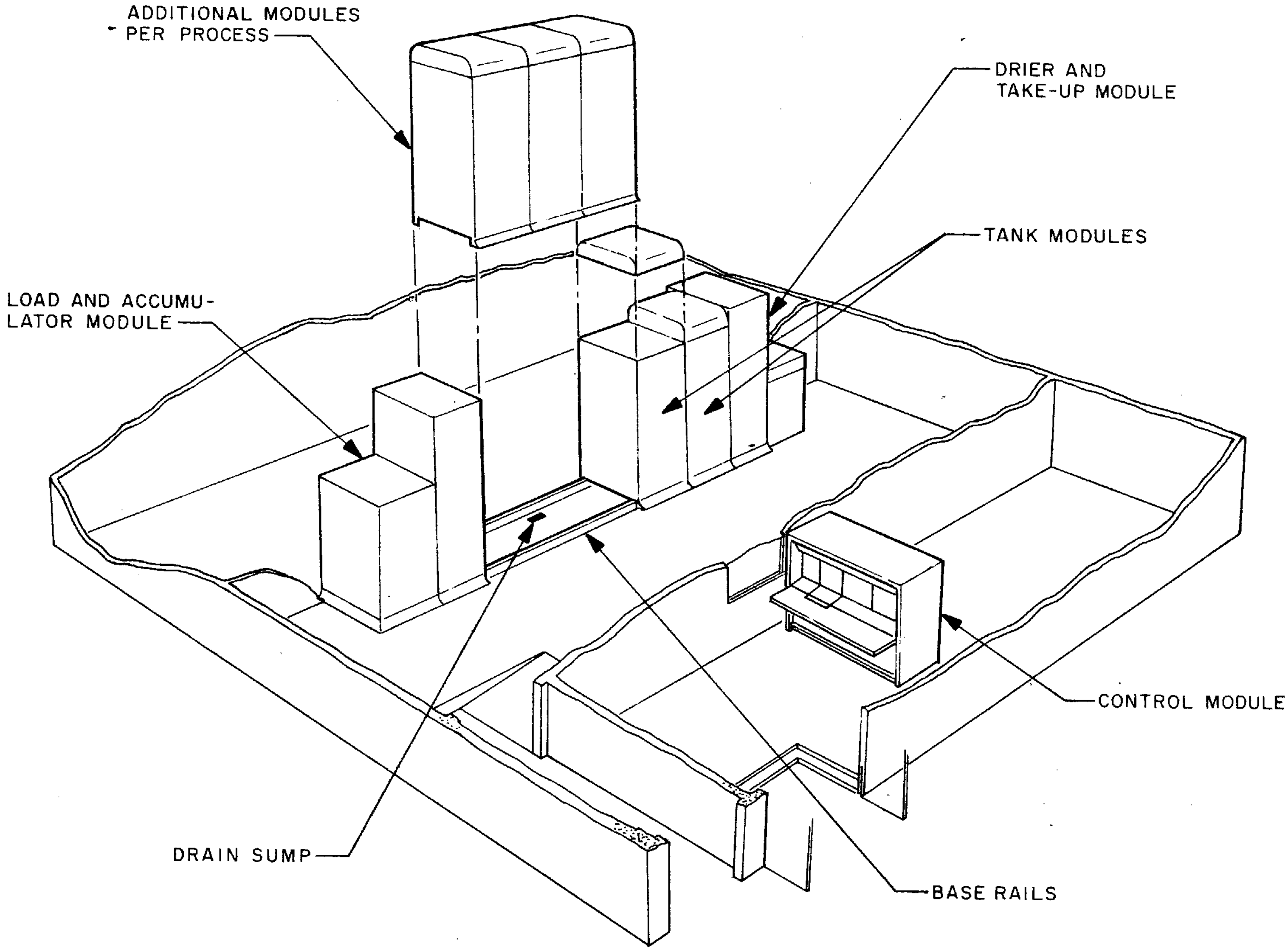

Figure 1. Typical Configuration of a Modular Processor

2) Applicability to all film widths from 70mm to 9-1/2 inches

3) Adaptability to the maximum number of three different emulsions and processing procedures

4) Controllability of temperature and all other processing parameters

5) Use of liquid and air bearings for the film throughout the processing

6) In addition, several criteria were assumed as preliminary design constants including:

a) Ambient cleanroom temperature of 68°F (20.0°C) with sufficient capacity to eliminate requirements for exterior heat and humidity sinks

b) Maximum processing solution temperature of 120°F (48.9°C)

c) Nominal film speed through processor 20 ft/min

d) Maximum time in any solution at maximum speed 2 min.

On the basis of the above criteria, preliminary design factors for the modular processor are outlined in the following paragraphs. It should be noted that several of the elements described are tentative and subject to modification as the result of detail design considerations and further experimentation. It is conceived that the processor as a whole will offer considerable flexibility. Adding or removing modules as required will accommodate all present and almost all advances in the art of photographic processing. In addition, each processing module in itself will be independently adaptable to modification of function or operation parameters as required to meet wide ranges of processing specifications.

A block diagram of the basic modular processor is shown in Figure 2.

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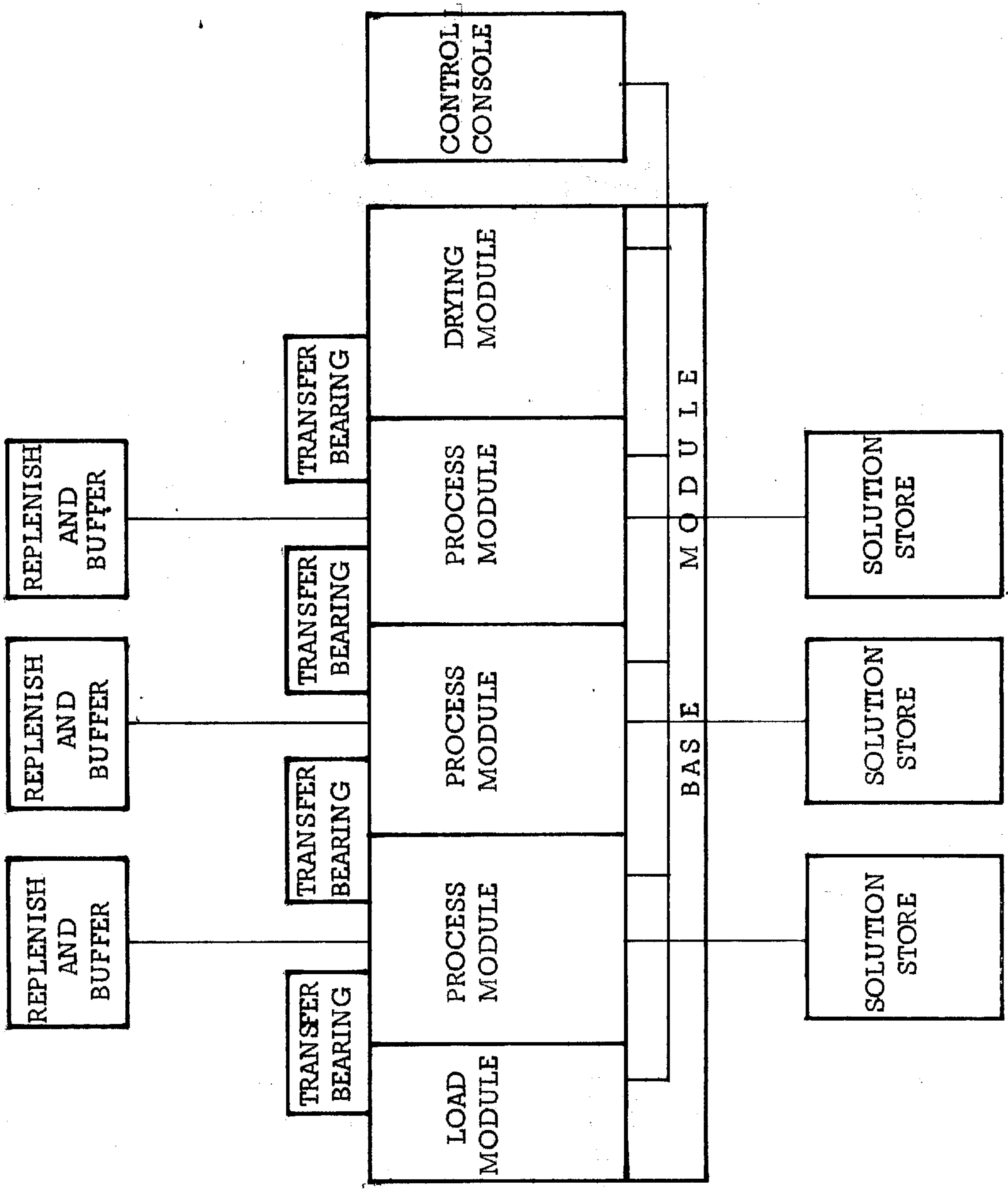

Figure 2. Modular Processor Block Diagram

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2.2 BASE AND INSTALLATION

2.2.1 Base

The base of the modular processor will serve to support the modules in accurate alignment, while permitting the interchange and addition of components without requiring elaborate procedures to maintain the accuracy of alignment required for rapid transfer of the film through the processor. The proposed base design would be a massive rail structure including precise flat and inverted "V" pads on opposite sides, as indicated in the cross section diagrams, Figures 3 or 4.

Flat tracks would be located along the base on which retractable casters would permit raising the modules clear of the pads so that they could be rolled onto or off the base as required for a given processing sequence.

The base would also carry a master conduit containing all power lines and connections between the control console and the modules. Suitable umbilical connectors would permit direct plug-in connection of each module to the master conduit as it is installed.

2.2.2 Installation

In most cases, installation of the base in a cleanroom would require permanent installation, carefully leveling and setting into the floor. Under such cleanroom conditions, a drain trough would be required, built into the floor, and suitable sealing means would be a part of the installation, including flush covers over the portions of the base not used in a given processing sequence assembly. This will also serve to isolate the drain trough from the cleanroom area.

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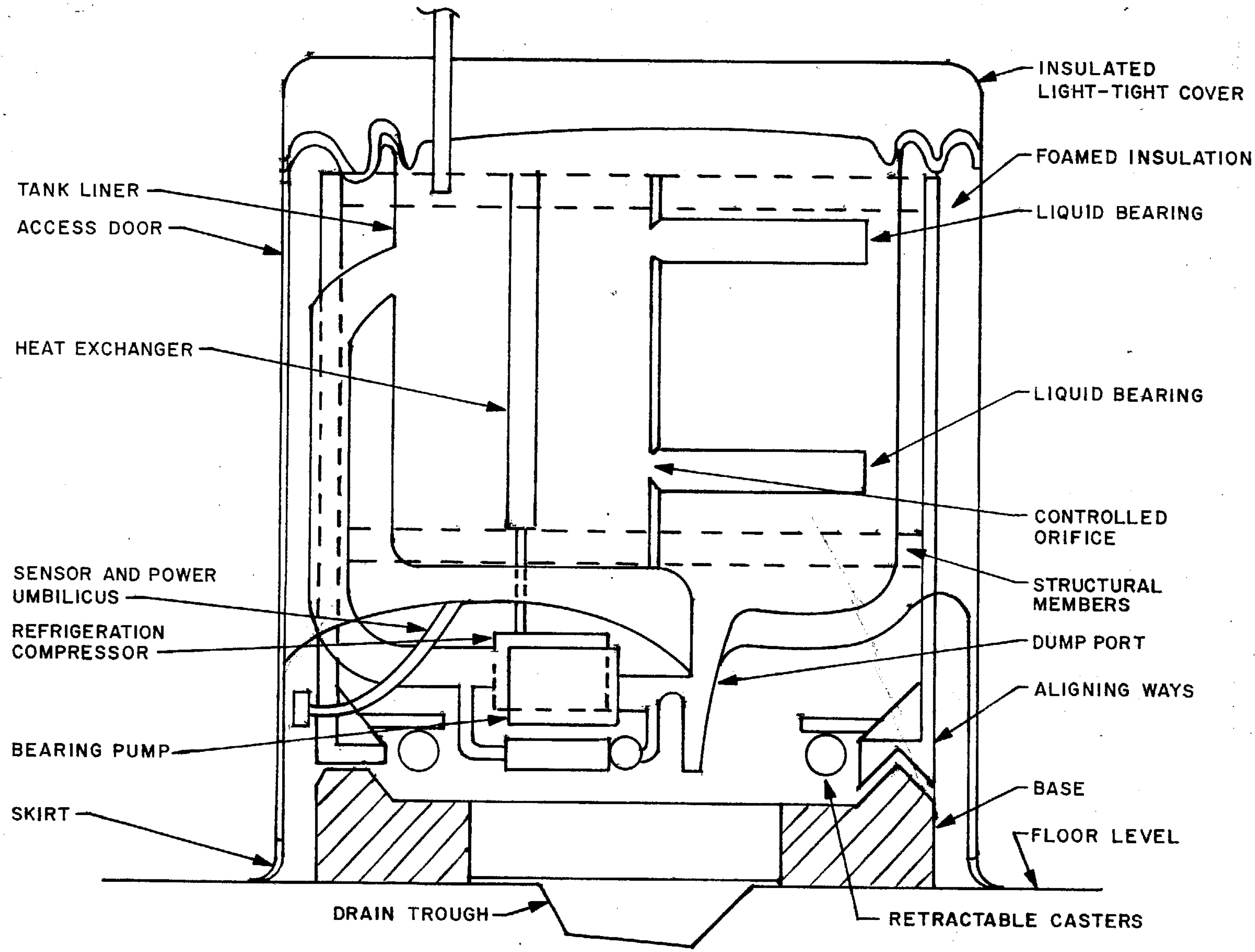

Figure 3. Diagrammatic Section of Solution Module with Current Jet-Type Bearings

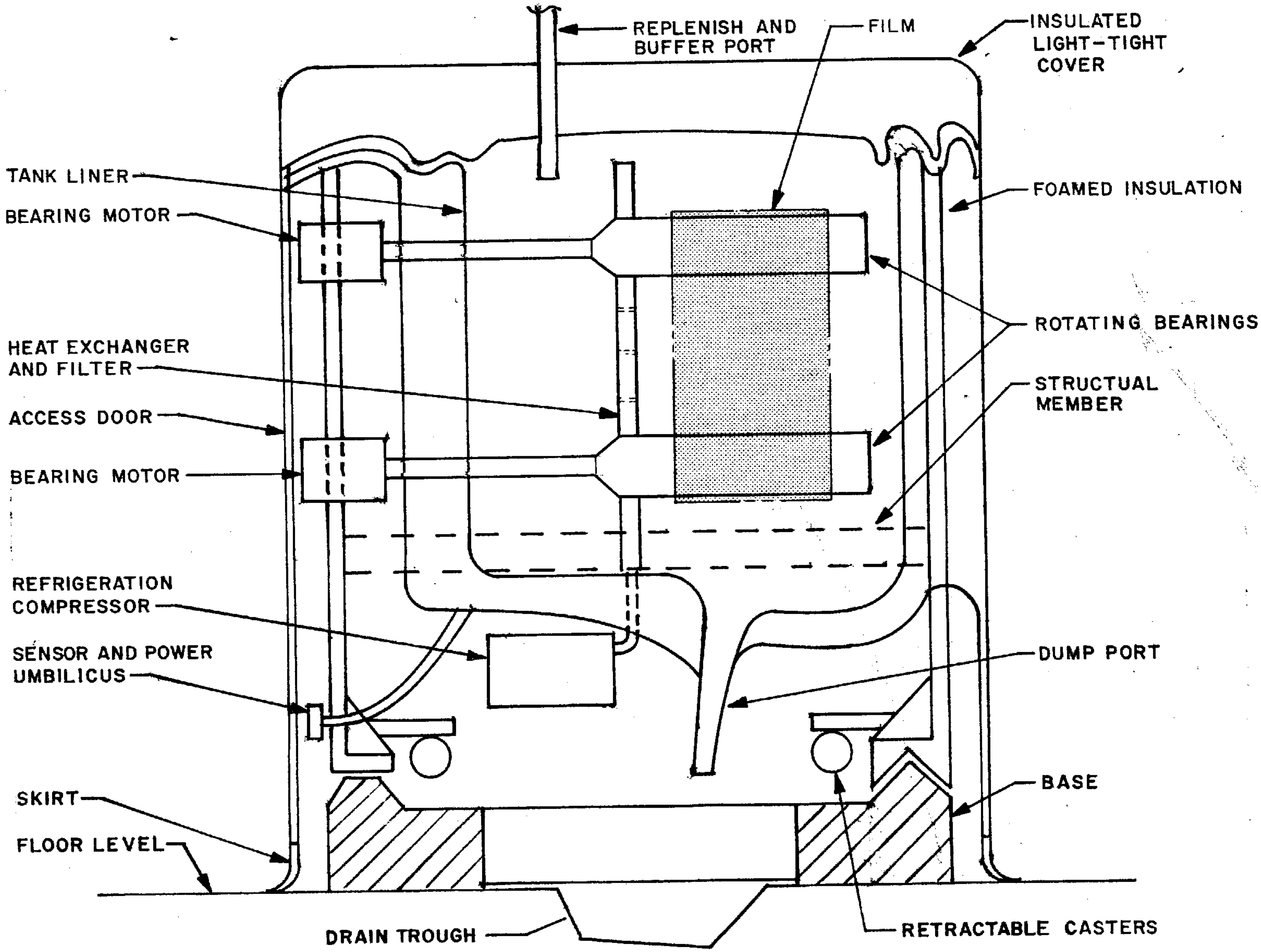

Figure 4. Diagrammatic Section of Solution Module with "Rotatron" Bearings

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Main solution tanks would preferably be outside the cleanroom area with suitable piping and pumping arrangements to bring the solution under the floor into the processing modules. Rapid disconnects would be used to connect the modules to these supplies.

In addition, overhead reservoirs would be used to contain replenishment and buffering solution which might be required to maintain constant processing parameters.

The modular processor would also be adaptable to less permanent installation without extremely stringent cleanroom conditions. For such a case, the base would be equipped with leveling screws and a portable troughing would be provided for drainage and installation of the connections to the processing supply.

2.3 CONTROL MODULE

Two alternative control modules are considered, differing in location and connection to the processor, but identical in function. These control modules will contain all meters, control switches, parameter computers, and all necessary valve controllers will be designed in accordance with accepted human engineering practice for optimum use by the operator. It may be located either in intimate association with the drying end of the processor or outside the cleanroom area. In either case, suitable protected cable connections will be provided to the master conduit.

Where the control console is outside the cleanroom area, the cable will be brought to it under the cleanroom floor. If the console is associated with the dry end, additional interlocks will be provided so that all illuminating lights on any of the meters or controls will be out if one of the light tight covers of any of the modules is opened.

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2.4 SOLUTION MODULE

The solution modules will be basically insulated stainless steel tanks in which the processing solutions and liquid bearings are arranged to provide path lengths varying from approximately 480 inches to as short as approximately 76 inches, to provide for various times in given processing solutions. The maximum length provides for two minutes processing at 20 ft/minute film speed. In processes where specifications called for a greater duration than this, the film speed will be reduced as required, or one or more duplicating modules containing the same solution will be inserted in the modular process. There are, however, considerations other than ability to contain the processing solution and vision of the required path length to be considered in the design of the modules.

2.4.1 Mechanical Structure

An important feature of the modular processor will be the accurate alignment of all the components. Each module will be constructed as a rigid structural framework resting on carefully aligned pads shaped to mode with the pad on the base in accurate alignment to the required tolerances. All bearings within the solution will be referred to the structural members of this framework and precisely aligned to the pads. Thus, minimal specific alignment procedures will be required in adding additional modules or removing any one module and replacing it with another. In addition, pins and sockets will also be provided on suitable vertical members to insure pairs of modules accurately looking to each other.

The structural framework will also support any pumps, motors, power supplies as well as the stainless steel tank lining and the exterior shrouding, (this last will be provided with suitable soft plastic base skirts to provide the required contact with the flooring as required for cleanroom operation).

2.4.2 Tank Lining and Shrouding

Since it is proposed to have a common modular structure for all tanks in the processor, this may involve solutions ranging in pH from 2.0 to 14.0 and solution temperatures up to 120°F. It is considered advisable to use only selected stainless steels in contact with the solutions. This dictates the material for module linings. In general, the tank section of the module will be divided into two compartments; a reservoir or plenum and the active processing compartment through which the film will pass over the liquid bearings. These compartments will be deep drawn or smooth welded with all corners suitably rounded for ready cleaning except at such orifices at which the contour will be controlled to regulate rates of flow. A small sump section will be provided in the processing section from which the dump drain and any pipe connections for bearing or filter pumps will originate. The tank liner will, of course, be rigidly attached to the structural framework of the module using only connective members which will minimize conductive transfer of heat from the tank lining to the structural member. This tank section will be surrounded by external shrouding which will merge into the total modular shrouds. A minimum space of 2 inches between the external shrouding and the tank liner will be filled with epoxy foam, foamed in position to provide a very high degree of thermal insulation between the contents of the tank and the ambient atmosphere. The material used for the shrouding may be either stainless steel or a plastic laminate, depending upon which is determined most suitable for cleanroom operation.

The only access to space within the shroud but below the tank proper, in which will be located any required pumps, power supplies, and electrical connections, will be through a single flush-access door on the back of each module.

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A removable top cover will be provided, again using stainless steel for the inner surface and the same exterior shrouding material, with the space between filled with epoxy foamed in place. The mating edges between the top of the tank and the cover will be designed to form a light trap with curves for easy cleaning. Provision will be made in this top cover for the proper installation of the modular air bearing structures that will be used for intertank transport of film.

2.4.3 Liquid Bearings

The solution modules contemplate two alternative types of liquid bearings for the support of the film through the processor. Each tank will contain 13 bearings in an array; 6 across the top, and 7 across the bottom. Threading over all provides for the maximum film length of approximately 480 inches. Both types of bearings will be designed to maintain centering of any width of film from 70mm to 9-1/2 inches. They also will be designed to permit modification of the loop over the bearing from 180° to 90°, as would be required for variations in threading path to accommodate shorter lengths of film in a given tank module. However, these two types of bearings operate on quite different principles and possess quite different hydrodynamic characteristics, and, hence, other elements of the modules will be affected by the final determination as to which type of bearing will be used. This decision will depend upon further detailed analysis and experimentation.

2.4.3.1 Current Jet-Type Bearings

The standard liquid bearing which has been incorporated in other [redacted] processors, supports the film by the efflux of liquid through shaped apertures in the bearing structure. Although there are several variations of the aperture configuration being considered, the general principles of this type of bearing is fairly consistent and requires the efflux of approximately 12 gallons per minute of liquid for proper support of film. The pump required to produce this volume of flow is quite substantial. In tanks using these bearings, the structure will be essentially as shown in the cross section diagram, Figure 3. The bearings will be supported by a relatively massive plate directly supported by the structural members of the module. The tank lining will merge with and be smoothly connected to the base of this plate. This will provide a continuous separator between the plenum and processing sections of the tank, interconnected only through the orifices in the bearings and the bearing pump connections.

The bearing pump will be selected to provide the necessary head to insure the movement of solution through all the bearings with sufficient velocity. In order to equalize the support provided by each bearing, two design elements are included. The heat exchanger within the plenum will be designed to also serve as an equalizing baffle so that none of the bearing ports will receive the full force of the stream from the bearing pump. In addition, provision will be made for inserting suitably sized and shaped orifices at each bearing intake to adjust the relative efflux through each bearing as required to maintain proper bearing support at each station under all threading paths.

In solution modules using this type of bearing it will also be necessary to employ a supplementary filtering pump. This will bypass some of the solution around the bearing pump, returning it to the plenum after passing through a filter which will remove all solid particles larger than 1 micron. The capacity of the filter pump and filter will be such that the entire tank full of solution will pass through the filter in approximately 15 minutes. Pressure effects of the filter pump will add essentially negligible boost to the bearing pump.

2.4.3.2 "Rotatron" Bearings

A new type of liquid bearing is being considered for use in this modular tank. It consists of a rotating fan structure which supports the film by the pumping action produced in the liquid. A diagramatic cross-section of a tank using these bearings is shown in Figure 4. The development and use of this type of bearing will simplify the structure of the solution module in several significant factors. It will be possible to reduce the mass solution required in a given tank module and to eliminate several external pumps. It also modifies and simplifies the internal structure of the tank. These bearings again will be supported by a rigid wall supported by the structural members of the module but with sealed shafts passing through the plenum driven by motors mounted within the shrouding, outside the tank. This partition now can also support the heat exchanger and a filter element.

With the mounting of the "Rotatron" bearings through the heat exchanger plate the provision of an additional circulating pump would not be necessary, since fluid would be drawn from the plenum section of the tank and developed through the bearing into the processor section. Since no considerable pressure differential is required between these two sections, the combined capacities of the liquid bearings should be sufficient to insure a flow through orifices in the heat exchanger.

2.4.4 Heat Exchanger

One of the most important features of the modular processor will be an independent control of temperature in various solutions used in a given process specification as well as the ability to accurately maintain the solution temperatures at the values called for by the specification.

It is, therefore, necessary to have within each module a heat exchanger suitable to maintain this specified temperature against an ambient controlled cleanroom temperature of 68°F. In most cases, even though the solutions are preconditioned in the supply tanks to a specified temperature, it will be necessary to add or remove additional heat. Most rapid process specifications call for elevating the temperature to relatively high values. Consequently, heating capacity to maintain a temperature up to 120°F will be provided. However, considerable heat will be dissipated to the solution by the pumps, and therefore, provisions must be also made for withdrawing additional heat to maintain the solutions at temperatures lower or close to the ambient. It is intended to employ a plate-type heat exchanger for this purpose in which heat will be added as required directly by resistive heating elements within the heat exchanger plate. This plate will be designed to also contain either tubular structures for liquid refrigerant or thermo-electric cooling elements.

In general, the required heat absorbing capacity of the heat exchanger plate will be much less than the required heating capacity to meet the specified extreme control temperatures. It is considered that adequate cooling capacity could be achieved with either a small compressor type refrigeration unit or a thermo-electric heat exchanger unit mounted in the space beneath the tank section of each solution module. It would then dissipate the removed heat to the space directly above the drain trough.

Heat replacement requirements, however, will be quite large even though the most efficient type of thermal insulation will be used around the tanks. One of the largest heat loss sources, which must be compensated for by the heat exchanger, arise from evaporative losses which result from the air bearing intertank connection. At the maximum temperature of 120°F this loss may be as large as 1/2 pound of water per minute. This would require an input of 500 BTU/per minute to maintain the required 120°F constant solution temperature if no other losses were present.

2.4.5 Sensors and Controls

Provision will be made in each tank module for installation of proper sensors and controls to maintain the specified processing parameters in all solutions. Some of these, such as solution temperature and solution depth controls, will be common to all modules and will be built into the module in a manner compatible with their continued proper function.

Other sensors and controllers would be required for particular solutions, as for example: pH monitoring, residual soluble silver detection, sulfur detection, etc. For such sensors and monitors, provisions will be made for ready installation as required. In all cases, the leads from these elements, as well as the power leads for each module, will be included in a common umbilical cable which will plug into the master conduit.

2.5 AIR BEARING TRANSFER MODULES

Between each module there will be a transfer station in which the film must be supported above the height of the module cover. This will be accomplished with the use of small modular air bearing components. These will engage in provided sockets in the module's mechanical structure. The air bearings used for the transfer will be based on one of the various types of air bearings designed by [redacted] Each module will be a self-contained unit consisting of the air bearing proper and its blower and plenum. For the transfer from or to a solution module, a lip of the air bearing will be below the solution surface constraining the lifting force of the air under the film, limiting film flutter. However, it should be noted that the flow rate of air through a conventional air bearing is of the magnitude of 150 cfm and in such a case, this volume of air will impinge on solution surface. At maximum solution temperature of 120°F, this volume of air will absorb water vapor and, hence, promote evaporation up to 1/2 pound per minute. The heat loss from the solution due to this rapid evaporation rate results in major heat loss in each module.

As an alternative to the tunnel type modular air bearing, supported above the tank module height, a self-powered air bearing may be employed. This unit would plug in through an overlapping junction plate between two tank modules and would be within the module cover. Suitably screened air intakes would be provided.

In some arrays where a large number of tank modules may be used for a given specified process (e.g. color film development), the placement of the drive capstan at the takeup end of the processor may cause excessive tension in the film or slippage on the capstan, due to the long length of film in transport. (See Report No. In such cases, to decrease the tension in the film and to relieve the torque load on the drive capstan one or more additional capstans, synchronized with the drive capstan, may be provided. These capstans would be interchangeable with the air bearing modules.

2.6 LOAD AND DRYING MODULES

The load and drying modules will be common to all processor assemblies. Consideration may be given to permanently mounting the drying module as a component part of the base structure.

On the other hand, the load module as the lightest component, particularly when empty, will be used as a file closer. That is, it will swing out of position to permit mounting or removing solution modules as required. The load module will be designed to accept all standard size reels and magazines up to 4000 feet capacity in all widths from 70mm to 9-1/2 inches, and will include a film accumulator to permit splicing.

The drying modules will primarily be conventional forced-air and heat dry labyrinth, vented to the exterior in a conventional manner. It is, however, conceived that within the same modular form, modified drying techniques such as vacuum assisted and desiccant assisted drying techniques may be incorporated as they become further developed. The term "conventional" implies that the heated air will be pumped through air bearings and used both to support the film and to dry it by impingement of the air on the film, i.e. the film will travel over a hot cushion of air.

3. CONCLUSIONS AND RECOMMENDATIONS

The preliminary considerations of the elements which would be involved in the design of a modular processor leads to the belief that such a unit would be feasible and a desirable addition to the art of processing photographic materials. The preceding discussion has considered very superficially many of the factors which would have to be further studied in considerable detail before producing definitive design of such a processor. It is recommended, therefore, that study of adapting various control parameters and techniques which previously have been incorporated in other [redacted] processors be considered for incorporation in such modules. Further research should be conducted on the most efficient

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means of implementing the heat exchange requirements. Design studies and experimentation to determine the advantages of various types of liquid bearings and air bearing transfer modules to such a modular concept of processor design will continue.

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